In-Service Performance Of Epoxy-Coated Steel Reinforcement In Bridge Decks

INTERIM REPORT

MATERIALS BUREAU
NEW YORK STATE DEPARTMENT OF TRANSPORTATION
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IN-SERVICE PERFORMANCE OF EPOXY-COATED STEEL REINFORCEMENT IN BRIDGE DECKS

INTERIM REPORT

Prepared By

Materials Bureau

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INTRODUCTION

This interim report provides preliminary results of an evaluation into the in-service performance of epoxy-coated steel reinforcement in bridge decks. A survey was undertaken at the request of the Department's Structural Concrete Committee in the summer and fall of 1990. The Materials Bureau performed field surveys on 14 bridges (26 spans) and laboratory evaluations on 54 deck cores. An additional 27 cores are being evaluated separately by the 3M Company and the Concrete Reinforcing Steel Institute (CRSI). Results of their evaluations are not complete and therefore are not included in this report.

A detailed final report on this project will be prepared when evaluations by 3M and CRSI, and additional analyses by the Materials Bureau, are complete.

PURPOSE

The purpose of this project is to assess the corrosion protection provided by epoxy coatings on steel reinforcement in bridge decks after at least seven years of service. The Department implemented a policy for the use of epoxy-coated bars in the top mat of steel reinforcement in November, 1976.

BRIDGE SAMPLE

A survey sample of 14 bridges, constructed or reconstructed between 1978 and 1983, was selected for evaluation. These bridges are seven to twelve years in age and represent some of New York State's oldest installations of epoxy-coated steel reinforcement.

A total of 26 spans were surveyed on the 14 structures. The wearing surface condition rating of these spans, as reported in the Bridge Inventory and Inspection System, ranged from five to seven. The wearing surface rating system for bridge decks is based on a numerical scale ranging from seven (new condition) to one (potentially hazardous). Appendix A describes the rating scale.

Three different brands of epoxy coating were used to coat the steel reinforcement: Scotchkote 213 and Scotchkote 214 manufactured by the 3M Company; and the Armstrong Product Company's Epoxiplate R349. Scotchkote 213 and 214 are presently available and approved for use in New York State. The Armstrong R349 epoxy is no longer being manufactured.

EVALUATION METHODS

The evaluation included field and laboratory phases.

A field evaluation consisting of visual, chain drag, and pachometer surveys was conducted on each of the 14 bridges in the sample. A visual survey was performed on one travel lane of each span to assess the condition of the bridge deck wearing surface, i.e., cracks, spalls, and patches. The chain drag survey was used to detect delaminations. A pachometer survey measured the thickness of concrete over the steel reinforcement, but was discontinued after the first few surveys. Differences between pachometer measurements and measured thicknesses of the concrete cover from cores varied from 1/4" to 2-1/2". These inconsistencies are believed due to the sensitivity of the pachometer to temperature changes.

Concrete cores of the bridge decks were obtained from 26 spans for later analysis at the laboratory. Cores were generally taken in wheelpaths at locations of cracks, delaminations, and patches, as well as in areas of no surface distress for reference. Cores were drilled to a depth below the top steel reinforcement to include the bar. Fifty-four cores were obtained for Materials Bureau laboratory analyses. An additional 27 cores were obtained for laboratory analyses by others, (3M Company and CRSI).

In the laboratory phase, cores were evaluated to determine concrete properties and epoxy coating performance. Each core was measured to record the actual thickness of concrete over the steel reinforcement. The presence, width, and depth of cracks were noted. Samples of concrete powder were obtained to determine pH and chloride level adjacent to the steel reinforcement. Thickness of the epoxy coating was measured, and the performance of the coating was visually assessed. The extent of corrosion, if present, was noted.

RESULTS

1. Field Phase

Transverse cracks were noted on all but one of the 26 spans evaluated. The cracks were normally less than 1/16" wide and extended over the width of the travel lane. Most spans contained five or more transverse cracks. No specific pattern regarding their spacing was observed, but most cracks were located near the center of spans.

There were no spalls in any of the bridge decks surveyed. Only one delamination was found, in a bridge deck that was 9 years old. The area of delamination measured 2 square feet (1'x2'). A core taken through the delamination indicated that the thickness of the concrete over the steel

reinforcement was 2-3/8". The delamination occurred 7/8" below the surface of the bridge deck, indicating that the delamination was unrelated to bar corrosion in the sample core.

2. Laboratory Phase

Appendix B is a printout of information in the data base established for the evaluation of the 54 cores by the Materials Bureau. It contains information from several sources: the Bridge Inventory and Inspection System data base, the field survey, and laboratory analyses. Forty (40) cores had steel reinforcement coated with the 3M's Scotchkote 213 epoxy, six (6) cores had bars coated with 3M's Scotchkote 214 epoxy, and eight (8) cores had bars coated with the Armstrong R349 epoxy.

a. Corrosion

Visual examination of the steel reinforcement removed from the 54 concrete cores found, for the most part, very minor corrosion. Corrosion, when it did occur, was limited to small areas. Corrosion normally appeared as pinpoints of rust, or on the raised bar deformations (ribs), or in small areas (<1/4"x1/4") on the body of the bar. Corroded areas were normally located on the top or side surfaces of bars that were directly exposed to cracks in the bridge deck. The severity of corrosion on rusted areas was superficial, or can be generally described as light rusting. No bar showed complete coating deterioration, and no bar had pits or loss of steel section. There was no undercutting of the epoxy coating surrounding a corroded area.

To describe the extent (not severity) of corrosion on the epoxy-coated steel reinforcement, the following scale was used:

1. **Negligible Corrosion.** No corrosion; or, no spot(s) of corrosion on the body of the bar greater than 1/4" x 1/4".

2. **Rib Corrosion.** Corrosion limited to the raised deformations (ribs); spot(s) of corrosion on the body of the bar less than 1/4" x 1/4".

3. **Bar Corrosion.** One or more corroded areas on the body of the bar greater than 1/4" x 1/4", in addition to corrosion on the raised deformations (ribs).

Although the scale is arbitrary, it is based on the Department's Standard Specification definition for distinguishing between major and minor epoxy coating damage. Defects or breaks in the coating 1/4" x 1/4" or greater are considered major damage and require field repairs with patching material. More than 5 major damaged areas in any 10' length of bar is cause for rejection. Also, the number of unrepaired minor damaged areas cannot exceed an average of 6 per foot on any individual bar.

Using this scale, a subjective evaluation of the extent of corrosion on the bars removed from the 54 concrete core sample was made. The findings were:

35 bars (65%) had "negligible" corrosion;
16 bars (30%) had only "rib" corrosion; and,
3 bars (5%) had "bar" corrosion.

The three bars with "bar" corrosion were obtained from different bridges. Their cores were taken from spans with deck defects. All cores had a crack extending to the steel reinforcement, providing a direct conduit for chloride contaminated water. In addition, one of the cores was taken from a span with a delamination, and another was taken from a span through a patched area. All of the bars were coated with 3M's Scotchkote 213 epoxy powder.

b. <u>Cracks</u>

The 54 cores were examined for cracks and other defects in the concrete that would, in effect, reduce the time for chlorides to reach the steel reinforcement and create a corrosive environment. Twenty-four (44%) of the cores had no cracks (**no crack**). Ten cores (19%) had cracks that did not extend to the depth of the steel reinforcement (**shallow crack**). Twenty cores (37%) had cracks that did extend to the steel reinforcement (**deep crack**).

Figure 1A shows the frequency of occurrence of the 54 cores in the different crack severity categories. Information on the extent of corrosion is superimposed for each category.

Figure 1B displays the data in Figure 1A differently to better show the apparent influence of cracks on corrosion. The number of cores having bars with a given extent of corrosion is expressed as a percent of total cores found in each crack severity category. All (100%) of the bars from the 24 cores without cracks were found to have "negligible" corrosion. For the 10 cores with shallow cracks, 8 bars (80%) had "negligible" corrosion and 2 bars (20%) had "rib" corrosion. There were no cores in this group that had bars with "bar" corrosion. For the 20 cores with deep cracks, only 3 bars (15%) were found to have "negligible" corrosion. Fourteen bars (70%) experienced "rib" corrosion, and the

remaining 3 bars (15%) had "bar" corrosion. Figure 1B suggests that corrosion is more likely to occur, and be more extensive, if the concrete cover protecting the steel reinforcement is cracked.

c. <u>**Concrete Cover Thickness**</u>

All bridge decks in this study were constructed under specifications requiring 2-1/2" ± 1/2" of Class E concrete over epoxy-coated steel reinforcement in the top mat. Department research estimates that with this 2-1/2" target depth of cover, a minimum cover depth of 2" will be obtained 92% of the time (FHWA-NY-RR67).

The measured, concrete cover thickness of the 54 cores averaged 2.873", and ranged from a minimum of 1.625" to a maximum of 4.250". Fifty-two (96%) of the 54 cores were found to be in compliance with the specification requiring a 2" minimum cover.

Figure 2A shows the distribution of the 54 sample cores by cover thickness. Information on the extent of corrosion is superimposed for each thickness category. Examination of this figure suggests that corrosion is more prevalent with thicker cover, which is contrary to common knowledge on corrosion of steel reinforcement in bridge decks. The presence of cracks, and their role in providing a path for chloride laden water to reach the steel reinforcement, is obscured by this figure.

Figure 2B shows the distribution of bar corrosion by cover thickness and also by crack category. Examination of this figure shows that the extent and severity of corrosion increases with the severity of crack category, for all thicknesses of concrete cover. This figure suggests that the performance of the epoxy coating is dependent on exposure to a corrosive environment. Cracks contribute to earlier, and thus more lengthy, exposure to chlorides.

d. <u>**pH Level**</u>

pH is an indicator of the extent to which concrete has carbonated. Fresh concrete is highly alkaline, and in this environment a passivating oxide layer forms on the steel reinforcement to protect against corrosion. Over time, atmospheric carbon dioxide combines with available lime in the concrete to form carbonates which lower the pH. Below a pH of about 9.5, the oxide protection layer begins to break down and expose the steel reinforcement to the corrosive environment ("NORCURE" literature, June 1990).

The pH level of the 54 cores at the depth of the steel reinforcement averaged 12.0 and ranged from a minimum of 11.7 to a maximum of 12.2. No relationship was found in the 54 core sample between pH of the concrete and extent of corrosion on the steel reinforcement.

e. Chloride Level

The amount of chloride that can be tolerated by steel in concrete before corrosion begins is not a unique number. It is dependent on several variables including pH of the concrete, the amount of soluble chloride present, and the moisture content. When other conditions are right, chloride values greater than 330 ppm on a concrete basis, or 1.3 lbs Cl/cy, have been associated with steel corrosion. This is considered the threshold value by the Department and FHWA.

Average chloride content of the concrete adjacent to the steel reinforcement for the 54 cores in this study sample was 962 ppm. This is almost triple the threshold value of 330 ppm (1.3 lbs/cy) necessary to provide a corrosive environment.

Figure 3 shows the distribution of the 54 study cores relative to the threshold chloride level, along with information on the extent of corrosion. The graph confirms that corrosion is more likely to occur when chloride levels are above the threshold chloride level.

f. Coating Thickness

The specification requirement for thickness of the epoxy coating on steel reinforcement is 5 to 9 mils. Average coating thickness on the sample of 54 bars was 8.99 mils and varied from 5.00 mils minimum to 13.75 mils maximum. All samples complied with specifications for minimum coating thickness.

Figure 4 shows the distribution of cores with coating thicknesses 5 to 9 mils (specification), and greater than 9 mils. There were no samples having a coating thickness less than 5 mils. Information on the extent of corrosion has been added. The graph suggests that coating thickness alone does not deter corrosion.

g. <u>Span Age and Wearing Surface Condition Rating</u>

Data for age and condition rating were obtained from the Bridge Inventory and Inspection System and were used to identify candidate bridge decks for this evaluation. Older bridge decks with lower wearing surface condition ratings were reasoned more likely to have corroded steel reinforcement.

Figures 5 and 6 give the frequency of occurrence of the 54 cores in terms of age, and in terms of wearing surface condition rating. Information on the extent of corrosion is superimposed in each figure. As can be seen, corrosion was found in young decks as well as old, and for decks in good condition as well as in distressed condition. Figure 5 suggests that other factors may be equal to, or more important than, age in determining extent of corrosion. Figure 6 has decks without corrosion in the category of Wearing Surface Condition = 5. This suggests that the wearing surface condition alone is not indicative of the condition of the epoxy-coated steel reinforcement in bridge decks.

DISCUSSION

In this study corrosion of the epoxy-coated steel reinforcement was not significant, and the corrosion protection provided by epoxy coatings appears satisfactory. However, it is difficult to assess the actual performance of epoxy-coated steel reinforcement because no basis for comparison has been adopted. Samples of unprotected (black) bars from bridge decks the same age as the sample bridges with epoxy-coated bars, and with 2 1/2" ± 1/2" cover, have not been evaluated to serve as standards for comparison. In 1976, when the epoxy-coated bar policy was implemented, epoxy coatings were expected to provide barrier protection to the steel for at least the design life of the bridge. Based on this study, epoxy coatings appear to have some finite life, yet to be determined.

The extent of corrosion in the study sample is minor and of little concern at this time. Corrosion generally appeared as light rusting and was restricted to small areas. The number and size of these areas, i.e. 1/4" x 1/4", in some cases might have warranted field repairs in accordance with the construction specifications. How and when these breaks in the epoxy coating occurred, and why field repairs were not performed as required by specifications, are questions that have no answer.

Transverse cracking in bridge decks has never been directly related to corrosion of the steel reinforcement (other than localized) in previous research by the Department. In the Engineering Research and Development Bureau's Special Report 11, transverse cracking was not believed to affect deck life. Even though the cracks are often narrow (1/16"), they provide a direct path for chloride laden water and atmospheric carbon dioxide to reach the steel reinforcement. This environment will promote corrosion at the bar level much earlier than expected in the life of the bridge deck. The presence of other contaminants, or exposure to wetting and drying cycles, may worsen conditions. How this environment affects the integrity of the barrier epoxy coating, is unknown at this time.

The significance of transverse cracks on the expected damage-free life of epoxy coated bars warrants further study. For unprotected decks with at least 2.25" of cover, the Engineering Research and Development Bureau projects a damage-free life of at least 16 years (FHWA/NY/SR-89/92). No such projections have been made for protected decks.

SUMMARY

To assess the corrosion protection provided by epoxy coatings on steel reinforcement in bridge decks, a sample of 14 bridges (26 spans) was selected for field survey and for laboratory analysis of deck cores. The bridges ranged in age from 7 to 12 years. Steel reinforcement was protected with one of three different kinds of epoxy coating: 3M's 213 (74% of the cores), 3M's 214 (11%), or Armstrong's R349 (15%). According to the Bridge Inventory and Inspection System, the Department constructed 659 bridges (1601 spans) with epoxy-coated steel reinforcement in the top mat. The policy to use epoxy coated bars with 2" minimum thick, Class E concrete cover was implemented in November, 1976.

The field survey of bridges in the study sample indicated that 25 of the 26 spans evaluated had transverse cracks in their decks. Only one delamination was detected. There were no spalls. A total of 81 cores were taken for laboratory analyses, 54 of which were evaluated by the Materials Bureau and are the subject of this report. The remaining cores are being evaluated by outside laboratories. Their findings will be included in a final report prepared by the Material Bureau.

Based on the Materials Bureau's laboratory sample evaluation of the bars from the 54 cores, corrosion is not a problem at this time. Corrosion of some significance, though not severe, was found on only three (5%) of the 54 bars. No bar showed complete coating deterioration, or pitting, or loss of steel section. There was no undercutting of the epoxy

coating surrounding a corroded area. These three bars were coated with 3M's 213 epoxy powder.

This study showed no strong relationship between corrosion and thickness of concrete cover, pH, chloride level, epoxy coating thickness, or deck age. While all are factors that are known to have some effect on corrosion, when singled out for analysis they show no independent relationship with extent of corrosion as characterized in this report.

The findings show that corrosion of the steel reinforcement is more extensive when associated with transverse cracks in the bridge deck. The protective epoxy coating appears to not perform as well under these circumstances. The significance of cracks in the bridge deck, and their relation to corrosion on epoxy-coated steel reinforcement warrants more study.

The final report will include additional and more detailed evaluations by the outside laboratories (3M and CRSI) on the performance of epoxy coatings. These findings will be incorporated with any additional evaluations by the Materials Bureau to provide a more complete understanding of epoxy coating performance in New York State. At this point, however, the coating appears to be performing satisfactorily.

APPENDIX A

WEARING SURFACE RATING SCALE

WEARING SURFACE CONDITION RATING SCALE

The Department rates bridge deck wearing surface condition as part of its biennial bridge inspections. A numerical scale from 7 (best) to 1 (worst) is used to rate the physical condition and riding quality of the wearing surface. When the surface is monolithic with the structural deck, as all the bridge decks in this study were, only the surface that the vehicles bear on is rated (as opposed to the full thickness of the wearing courses).

When inspecting bridge deck wearing surfaces, the riding quality across the bridge is the major factor in determining a rating. A slippery wearing surface, for example, is rated low. For the decks in this study, the presence, severity and extent of defects like scaling, spalling, cracking, and rutting were also taken into consideration.

The numerical rating scale used to rate the condition of concrete monolithic bridge deck wearing surfaces is described below in general terms.

RATING SCALE

7 - Like-new condition

5 - Good riding quality. Large areas of the surface are in good condition; minor evidence of deterioration.

3 - Serious deterioration of the surface. Extensive cracking and spalling; riding quality is seriously affected.

1 - Potentially hazardous. Complete deterioriation of the surface; poor riding quality.

Ratings of 2, 4, or 6 are used to shade between the other ratings.

APPENDIX B

FIELD AND LABORATORY DATA

EPOXY-COATED STEEL REINFORCEMENT SURVEY

DATA BASE KEY

BRIDGE DATA

BIN - Bridge Identification Number
REG - Region number
YR-BLT - Year built
YR-REH - Rehabilitation year
AGE - Bridge age
AADT - Annual average daily traffic

SPAN DATA

SPAN - Span number
LENGTH - Span length (feet)
WR - Wearing surface condition rating
SPCR - Span with cracks
SPDEL - Span with delaminations

CORE DATA

CORE - Core number
NOCR - Core with no crack
SCR - Core with shallow crack
DCR - Core with deep crack
DEL - Core taken from delaminated area

BAR DATA

PH - pH of concrete at bar level
CL - Chloride content of concrete at bar level
DFT - Dry film thickness of epoxy coating
C-COV - Measured concrete thickness
NC - Bar with negligible corrosion
RC - Bar with rib corrosion
BC - Bar with bar corrosion

EPOXY COATED STEEL REINFORCEMENT SURVEY

LAB CORES

COATING	BIN	REG	YR-BLT	YR-REH	AGE	AADT	SPAN	LENGTH	WR	SPCR	SPDEL	CORE	NOCR	SCR	DCR	DEL	PH	CL	DFT	C-COV	NC	RC	BC	COMMENTS
3M/213	1017600	09	1979	--	11	3850	1	107	5	X		1		X			12.0	71	8.00	2.750	X			
		09	1979	--	11	3850	1	107	5	X		2	X				12.0	392	5.75	2.000	X			
		09	1979	--	11	3850	1	107	5	X		3			X		11.9	428	9.25	2.250	X			
		09	1979	--	11	3850	2	84	5	X		1	X				11.9	0	8.75	3.250	X			Patch
		09	1979	--	11	3850	2	84	5	X		2	X				11.8	36	8.50	2.750	X			Wood in deck
		09	1979	--	11	3850	2	84	5	X		3	X				11.9	0	8.50	3.250	X			
	1027060	09	1953	1978	12	2200	1	44	6	X		1			X		11.7	1,641	9.00	3.000		X		
		09	1953	1978	12	2200	1	44	6	X		2			X		11.8	785	12.00	3.000		X		
		09	1953	1978	12	2200	1	44	6	X		3	X				11.9	1,606	7.50	2.375	X			
		09	1953	1978	12	2200	2	152	6	X		1	X				11.8	928	13.75	3.250	X			
		09	1953	1978	12	2200	2	152	6	X		2			X		11.9	1,142	8.75	3.125	X			
		09	1953	1978	12	2200	2	152	6	X		3			X		11.8	2,854	10.50	2.375			X	Patch
		09	1953	1978	12	2200	3	66	5	X		1	X				11.9	535	5.00	3.000	X			
		09	1953	1978	12	2200	3	66	5	X		2			X		11.9	1,142	8.25	3.000		X		
		09	1953	1978	12	2200	3	66	5	X		3		X			11.9	1,106	7.25	3.000	X			
	1040070	03	1934	1979	11	360	1	80	6	X		1			X		12.1	1,499	9.50	2.750		X		
		03	1934	1979	11	360	1	80	6	X		2		X			11.9	1,855	7.00	2.250		X		
		03	1934	1979	11	360	1	80	6	X		3	X				11.9	214	11.25	2.000	X			
	1040080	03	1924	1979	11	360	1	37	6			1	X				11.9	3,211	13.00	1.625	X			
		03	1924	1979	11	360	1	37	6			2	X				12.0	2,426	11.25	2.375	X			
	1052020	02	1931	1979	11	2850	1	60	6	X		1	X				11.9	3,068	8.75	2.000	X			
		02	1931	1979	11	2850	1	60	6	X		2			X		12.0	1,213	8.75	2.125	X			
	1070700	01	1981	--	9	3850	1	149	7	X	X	4			X		12.0	2,605	10.25	3.000			X	
		01	1981	--	9	3850	2	149	7	X		5			X		12.1	1,820	12.00	2.250		X		
	1071010	09	1979	--	11	5350	1	105	6	X		1			X		12.0	999	12.50	4.250			X	
		09	1979	--	11	5350	1	105	6	X		2	X				12.0	107	9.75	4.000	X			
		09	1979	--	11	5350	2	126	6	X		1	X				12.0	71	12.25	3.375	X			
		09	1979	--	11	5350	2	126	6	X		2		X			12.0	214	10.75	4.250	X			
		09	1979	--	11	5350	3	105	5	X		1			X		12.0	1,249	11.50	4.250		X		
		09	1979	--	11	5350	3	105	5	X		2			X		11.9	285	8.50	4.250		X		
		09	1979	--	11	5350	3	105	5	X		3	X				11.9	214	8.50	3.750	X			

EPOXY COATED STEEL REINFORCEMENT SURVEY

LAB CORES

COATING	BIN	REG	YR-BLT	YR-REH	AGE	AADT	SPAN	LENGTH	WR	SPCR	SPDEL	CORE	NOCR	SCR	DCR	DEL	PH	CL	DFT	C-COV	NC	RC	BC	COMMENTS
3M/213	1071111	04	1980	--	10	17100	1	240	6	X		1			X		12.0	1,891	8.80	3.250		X		
		04	1980	--	10	17100	1	240	6	X		2			X		12.0	2,391	7.90	3.125		X		
		04	1980	--	10	17100	2	240	6	X		3		X			12.1	1,427	7.70	3.500		X		
		04	1980	--	10	17100	3	200	6	X		1	X				12.0	392	7.00	2.250	X			
		04	1980	--	10	17100	3	200	6	X		2		X			12.0	607	7.40	3.250	X			
		04	1980	--	10	17100	3	200	6	X		3			X		12.2	1,641	7.30	3.000		X		
		04	1980	--	10	17100	4	180	6	X		1	X				12.0	143	8.90	2.625	X			
		04	1980	--	10	17100	4	180	6	X		2		X			12.1	1,284	7.60	3.375	X			
		04	1980	--	10	17100	4	180	6	X		3		X			12.1	1,570	8.90	3.000	X			
Count:	8											40	16	8	16	0					25	12	3	
Minimum:					9				5								11.7	0	5.00	1.625				
Maximum:					12				7								12.2	3,211	13.75	4.250				
Average:																	12.0	1,127	9.19	2.956				
3M/214	1000530	07	1948	1983	7	6550	1	167	7	X		1			X		12.0	1,070	7.90	2.500		X		
		07	1948	1983	7	6550	1	167	7	X		2			X		12.0	0	7.00	4.000		X		
	1000540	07	1948	1983	7	6550	1	219	6	X		2	X				12.1	0	6.50	2.250	X			
	1072300	10	1983	--	7	13600	1	78	6	X		1	X				11.8	0	7.30	2.875	X			
		10	1983	--	7	13600	1	78	6	X		2			X		12.0	963	5.80	3.375		X		
		10	1983	--	7	13600	2	112	6	X		4	X				12.1	0	6.90	3.250	X			
Count:	3											6	3	0	3	0					3	3	0	
Minimum:					7				6								11.8	0	5.80	2.250				
Maximum:					7				7								12.1	1,070	7.90	4.000				
Average:																	12.0	339	6.90	3.042				
ARM/R349	1069800	02	1980	--	10	700	1	98	7	X		1		X			12.0	103	9.25	2.000	X			
		02	1980	--	10	700	1	98	7	X		2	X				12.1	214	7.75	2.000	X			
	107086C	01	1981	--	9	38900	1	175	5	X		3	X				11.8	392	8.49	2.875	X			
		01	1981	--	9	38900	2	220	5	X		3			X		11.9	821	7.65	3.250		X		

EPOXY COATED STEEL REINFORCEMENT SURVEY
LAB CORES

COATING	BIN	REG	YR-BLT	YR-REH	AGE	AADT	SPAN	LENGTH	WR	SPCR	SPDEL	CORE	NOCR	SCR	DCR	DEL	PH	CL	DFT	C-COV	NC	RC	BC	COMMENTS
ARM/R349	3312170	03	1981	--	9	900	1	92	6	X		1		X			12.0	428	11.25	2.000	X			
		03	1981	--	9	900	1	92	6	X		2	X				12.0	571	11.25	2.375	X			
		03	1981	--	9	900	2	92	7	X		1	X				12.0	1,784	10.75	1.750	X			
		03	1981	--	9	900	2	92	7	X		2	X				11.9	535	9.75	2.375	X			
Count:	3											8	5	2	1	0					7	1	0	
Minimum:					9				5								11.8	103	7.65	1.750				
Maximum:					10				7								12.1	1,784	11.25	3.250				
Average:																	12.0	606	9.52	2.328				
Count:	14											54	24	10	20	0					35	16	3	
Minimum:					7				5								11.7	0	5.00	1.625				
Maximum:					12				7								12.2	3,211	13.75	4.250				
Average:																	12.0	962	8.99	2.873				

APPENDIX C

DATA SUMMARIES--FIGURES 1 THRU 6

FIGURE 1A

DISTRIBUTION OF CORES BY CRACK CATEGORY

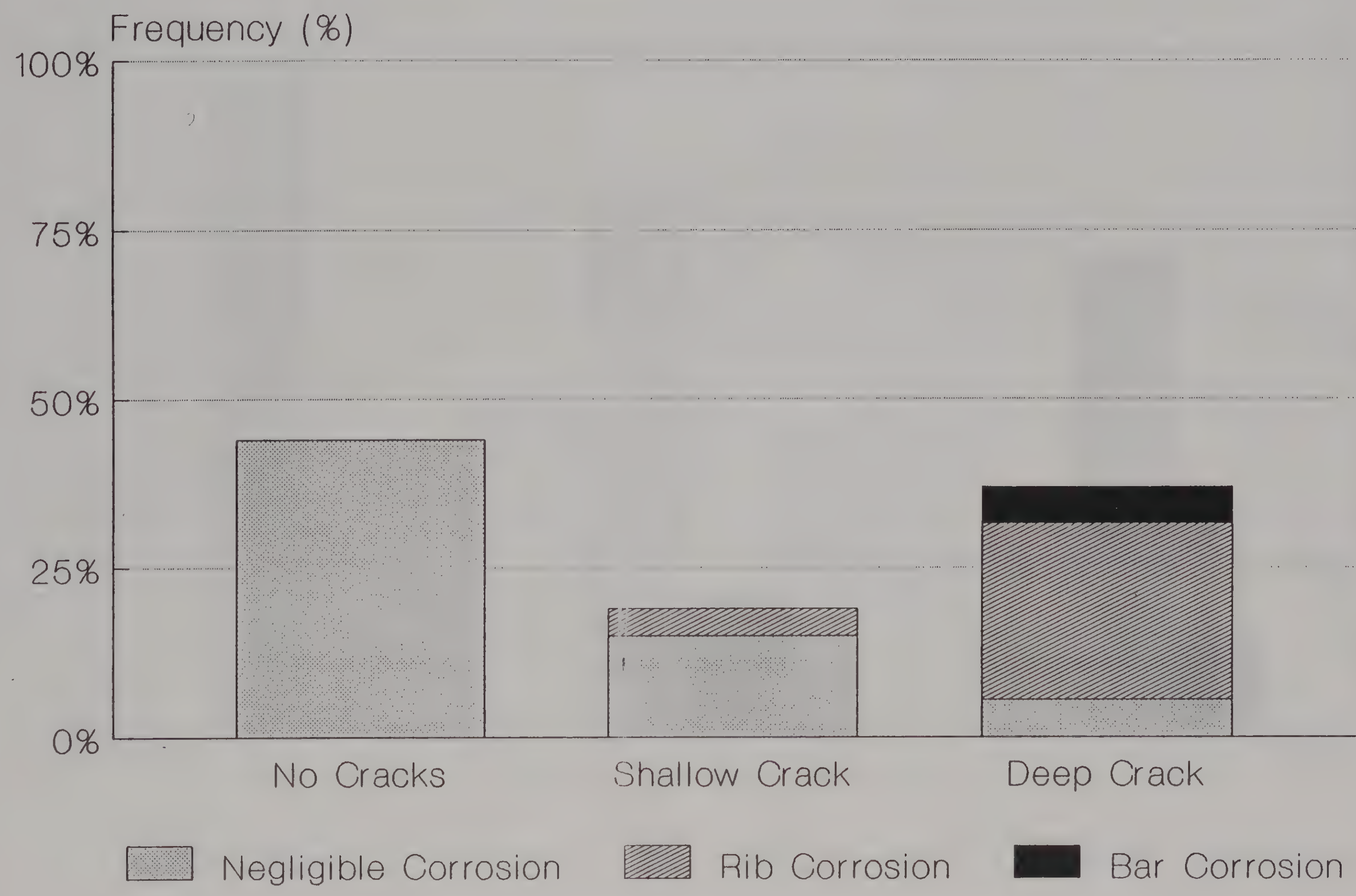


FIGURE 1B

DISTRIBUTION OF BAR CORROSION BY CRACK CATEGORY

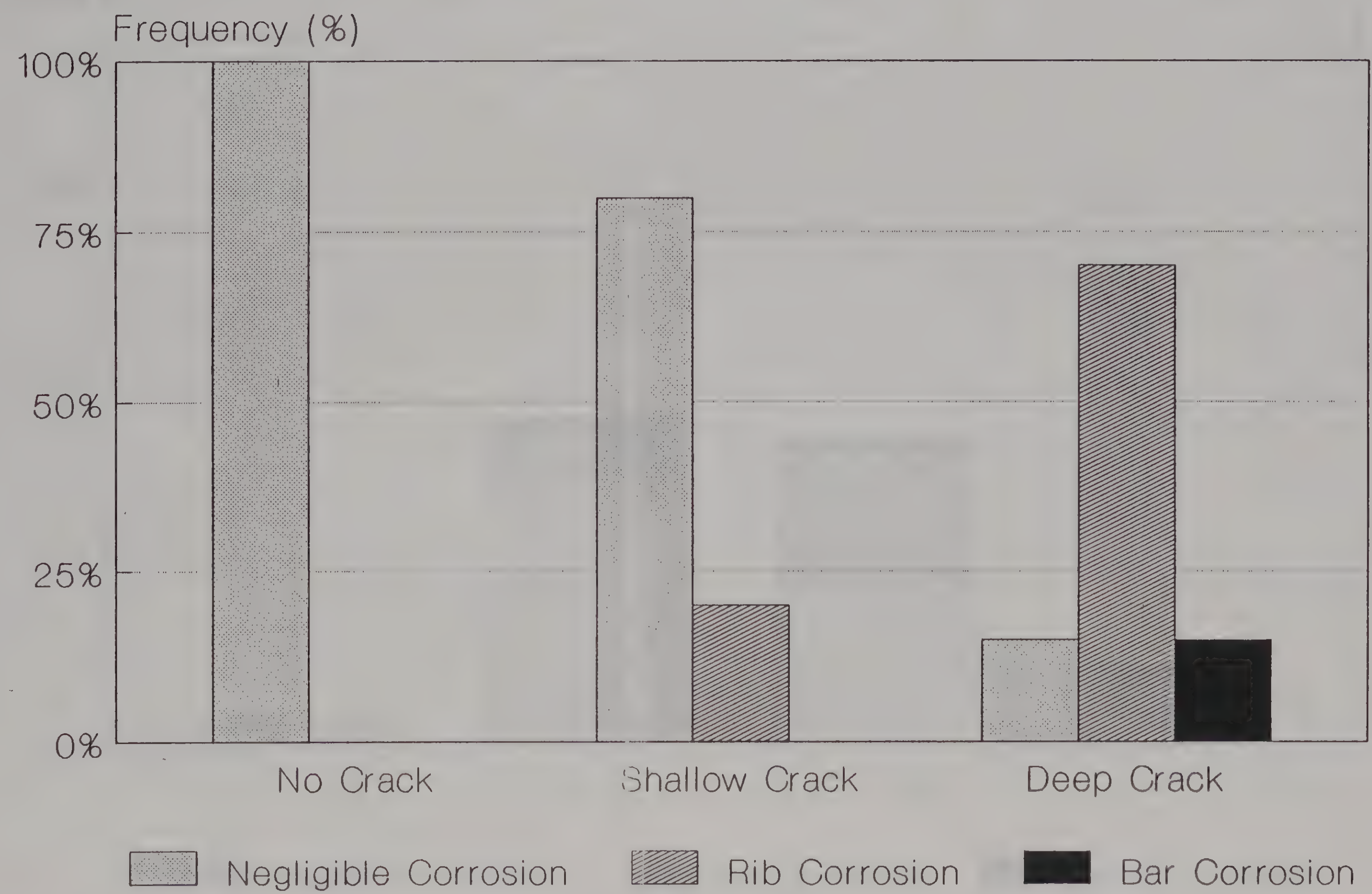


FIGURE 2A

CONCRETE COVER AND CORROSION

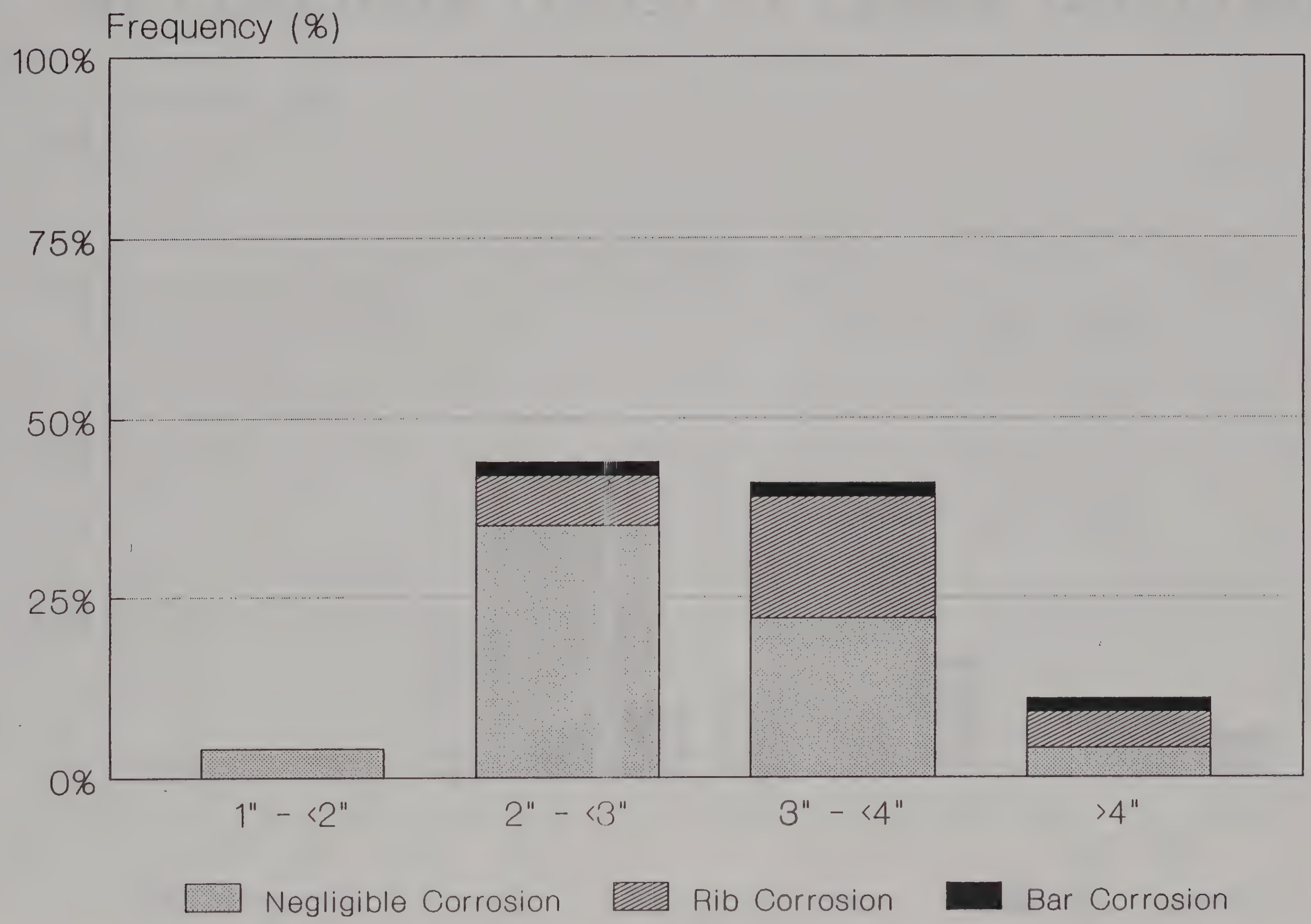


FIGURE 2B

DISTRIBUTION OF BAR CORROSION BY CONCRETE COVER BY CRACK CATEGORY

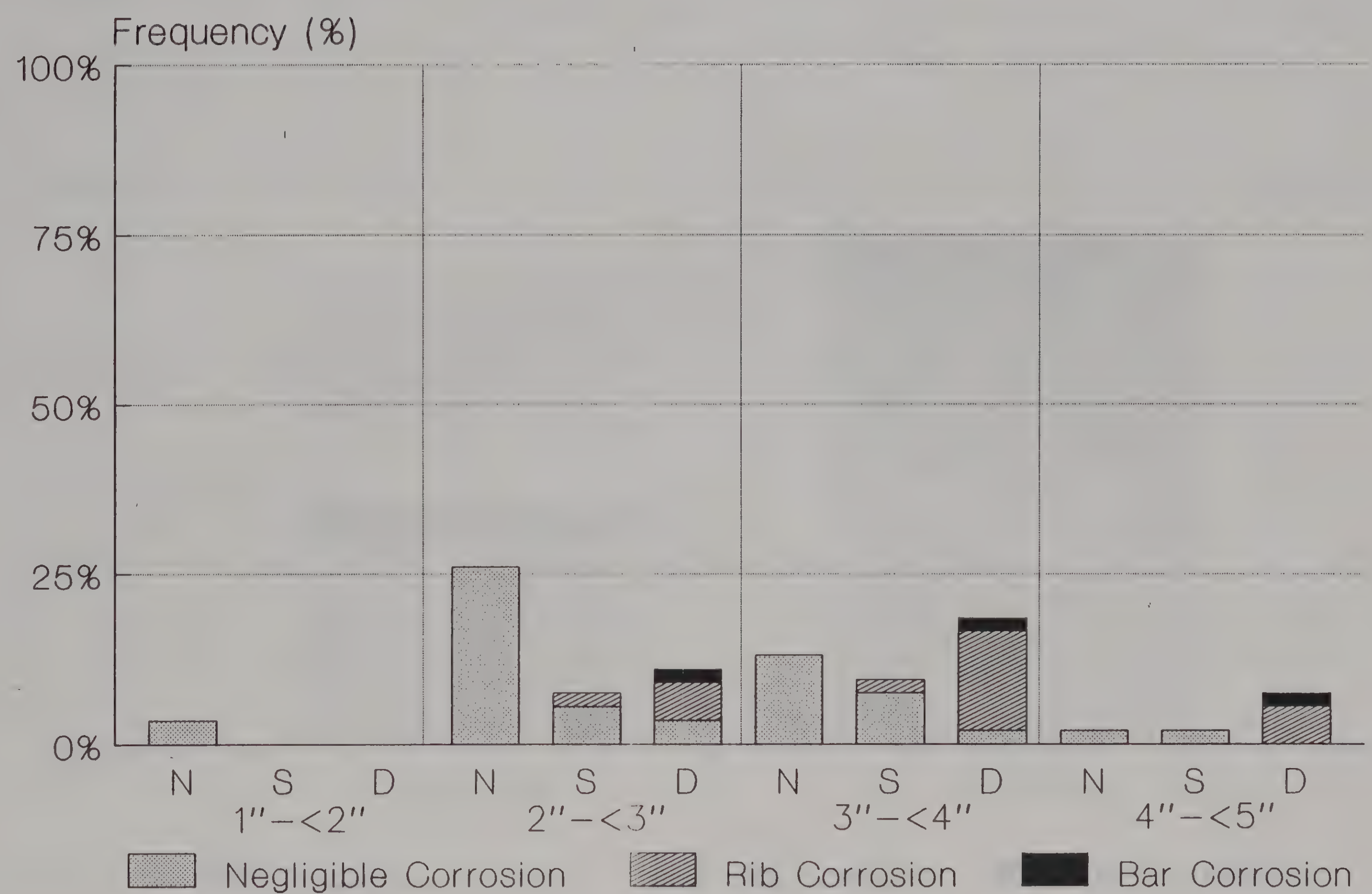


FIGURE 3

CHLORIDES AND CORROSION

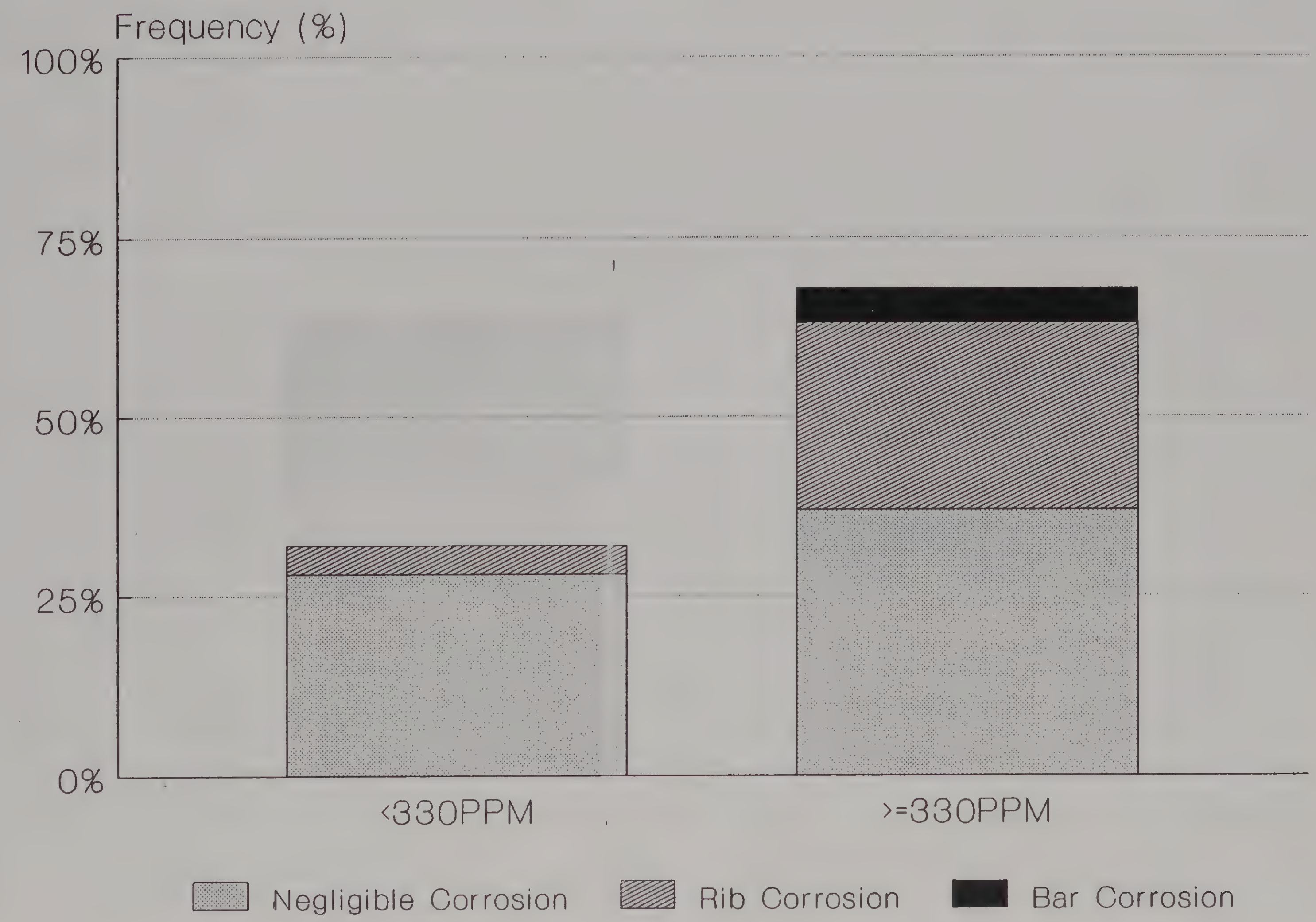


FIGURE 4

COATING THICKNESS AND CORROSION

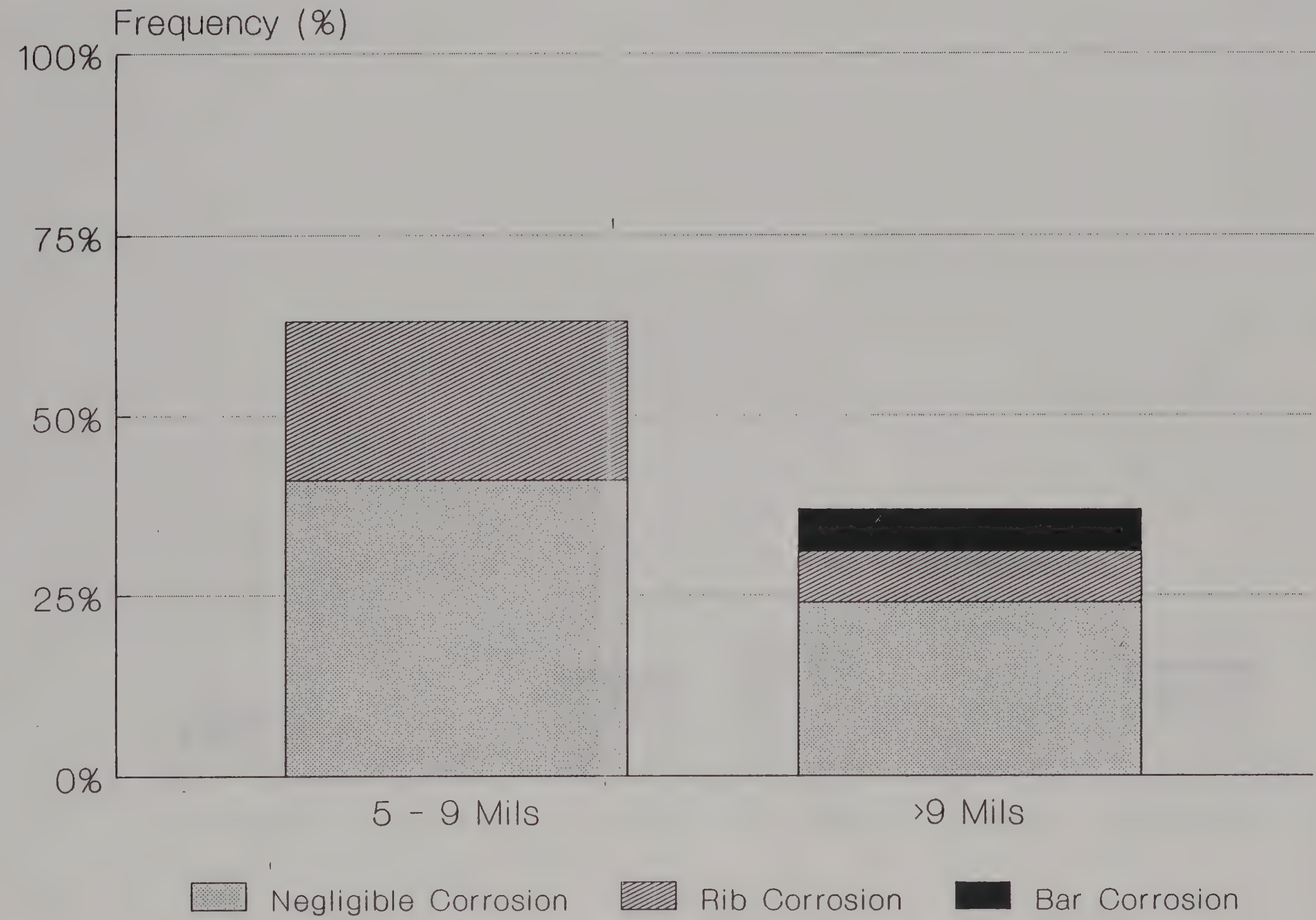
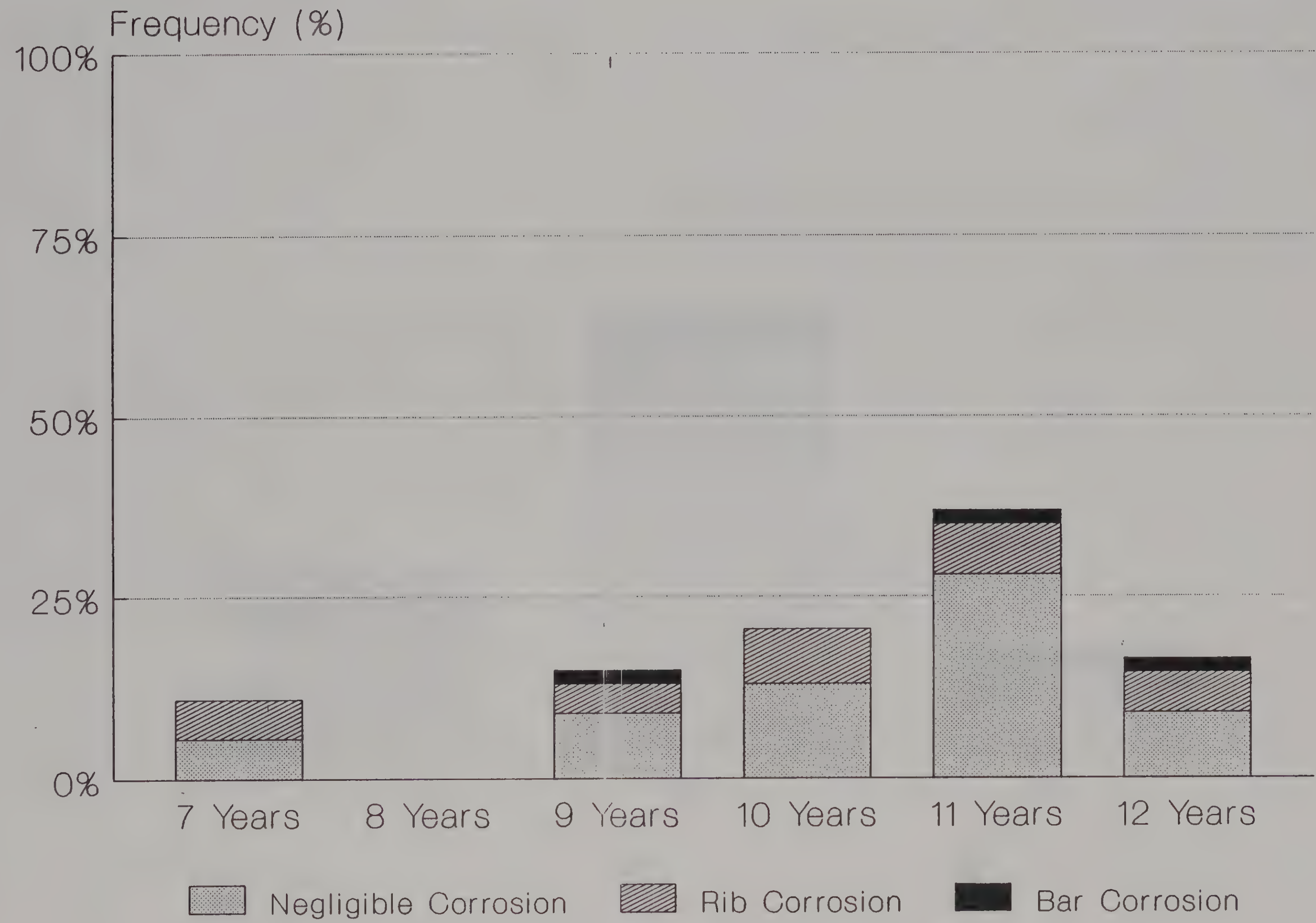


FIGURE 5

SPAN AGE AND CORROSION



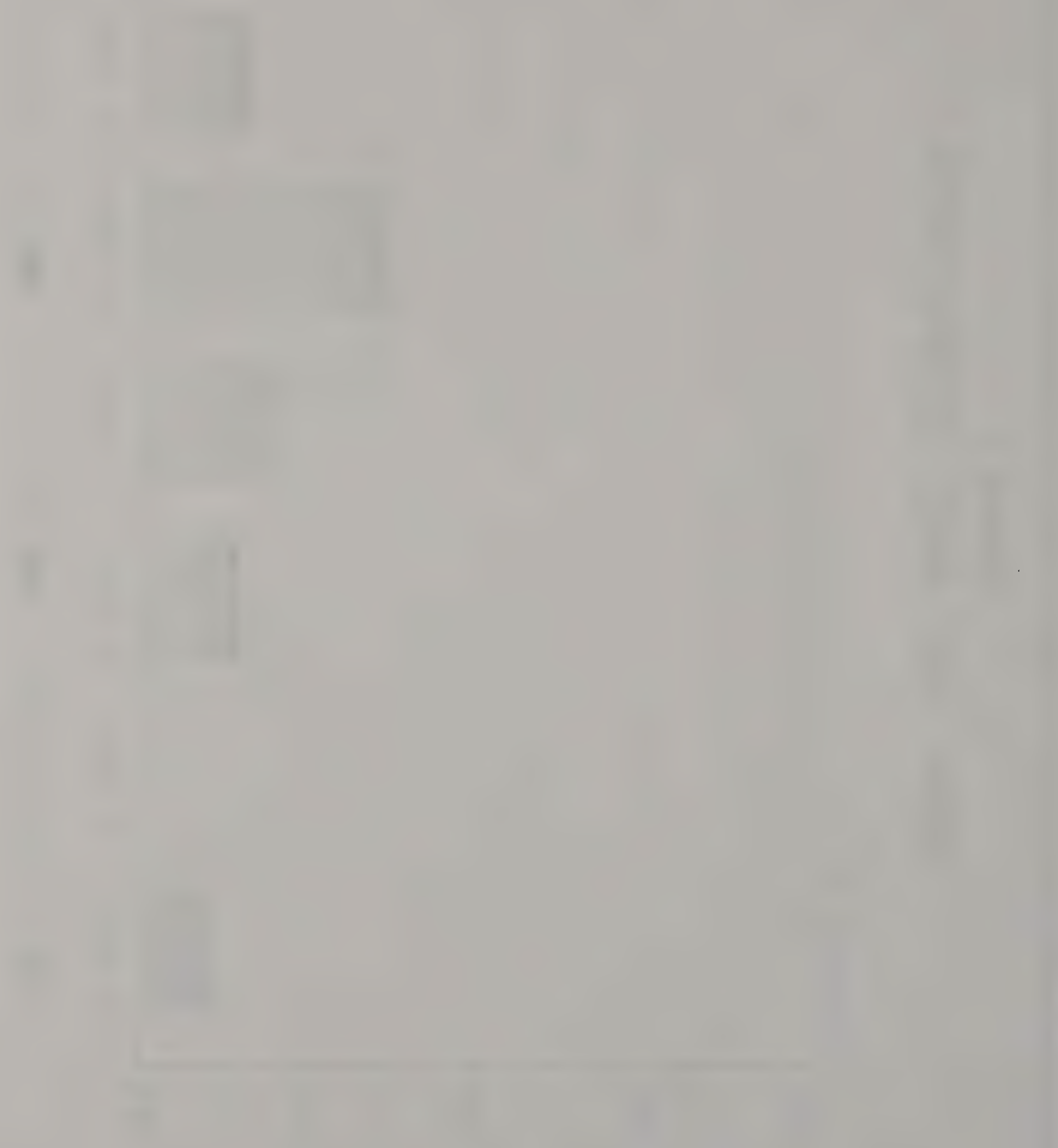


FIGURE 6

WEAR RATING AND CORROSION